(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
8 February 2001 (08.02.2001)

PCT

(10) International Publication Number
WO 01/10182 A2

(51) International Patent Classification[7]: H05K 9/00

(21) International Application Number: PCT/US00/20609

(22) International Filing Date: 28 July 2000 (28.07.2000)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/146,534 30 July 1999 (30.07.1999) US

(71) Applicant *(for all designated States except US)*: AMESBURY GROUP, INC. [US/US]; 57 Hunt Road, Amesbury, MA 01913 (US).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: KAPLO, Joseph, J. [US/US]; 463 Exeter Road, Hampton, NH 03842 (US). ALALFI, Ashraf [US/US]; 2 Mason Court, Amesbury, MA 01913 (US).

(74) Agent: SULLIVAN, Joseph, P.; Testa, Hurwitz & Thibeault, LLP, High Street Tower, 125 High Street, Boston, MA 02110 (US).

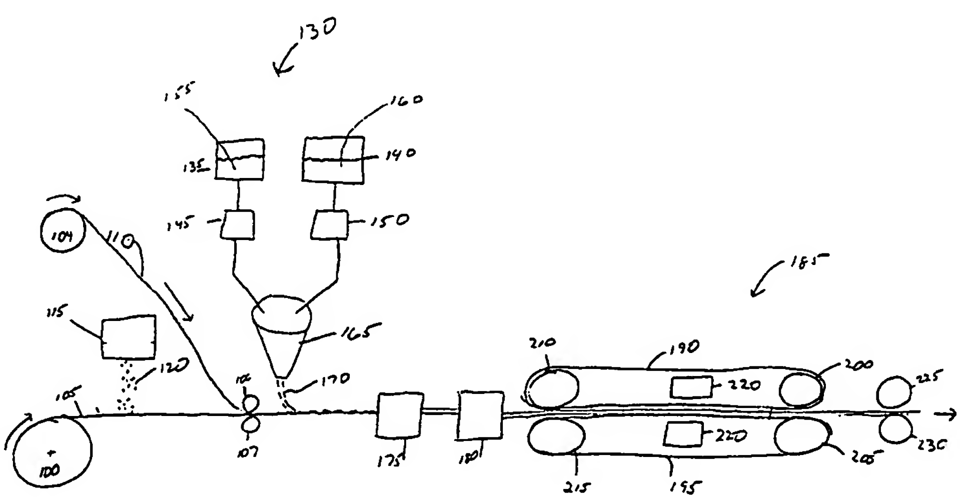
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).

Published:
— *Without international search report and to be republished upon receipt of that report.*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: METHOD AND APPARATUS FOR MANUFACTURING A FLAME RETARDANT EMI GASKET



(57) Abstract: An electromagnetic interference shield that meets flammability standards for use in electronic equipment enclosures such as computer cabinets and other electronics includes a resilient foam core, an expandable carbon graphite layer, and a metallized fabric outer layer. The shield may be manufactured on a process line which forms, laminates, and bonds the elements together.

WO 01/10182 A2

METHOD AND APPARATUS FOR MANUFACTURING A FLAME RETARDANT EMI GASKET

Related Applications

This application claims priority to and incorporates herein by reference in its entirety U.S. Provisional Application Serial No. 60/146,534, filed July 30, 1999, entitled Method and Apparatus For Manufacturing A Flame Retardant EMI Gasket.

Field of the Invention

This invention relates to electromagnetic interference ("EMI") gaskets and shields, and, more specifically, to flame retardant EMI gaskets manufactured from a foam core laminated by a metallized fabric or other electrically conductive material or covering with a layer of expandable carbon graphite placed between the foam core and metallized fabric.

Background of the Invention

During normal operation, electronic equipment generates undesirable electromagnetic energy that can interfere with the operation of proximately located electronic equipment due to EMI transmission by radiation and conduction. The electromagnetic energy can by of a wide range of wavelengths and frequencies. To minimize the problems associated with EMI, sources of undesirable electromagnetic energy may be shielded and electrically grounded. Shielding is designed to prevent both ingress and egress of electromagnetic energy relative to a housing or other enclosure in which the electronic equipment is disposed. Since such enclosures often include gaps or seams between adjacent access panels and around doors and connectors, effective shielding is difficult to attain because the gaps in the enclosure permit transference of EMI therethrough. Further, in the case of electrically conductive metal enclosures, these gaps can inhibit the beneficial Faraday Cage Effect by forming discontinuities in the conductivity of the enclosure, which compromise the efficiency of the ground conduction path through the enclosure. Moreover, by presenting an electrical conductivity level at the gaps that is significantly different from that of the enclosure generally, the gaps can act as slot antennae, resulting in the enclosure itself becoming a secondary source of EMI.

An area of concern regarding electronic enclosures, such as those used to house personal computers and the like, is the potential for a fire to start in the electrical enclosure. Due to this concern certain components of the electrical enclosure are generally required to meet flammability standards.

Summary of the Invention

A flame retardant EMI shield, according to one embodiment of the invention, overcomes many of the limitations and disadvantages of conventional EMI shields. In one embodiment, expandable carbon graphite is applied to an interior surface of an electrically conductive covering, such as a metallized fabric. A foam core is then disposed on or formed in the metallized fabric and subsequently laminated by and bonded to the metallized fabric, thereby encasing the expandable carbon graphite to provide flame retardant performance characteristics to the shield.

An EMI shield according to the invention combines effective EMI shielding, due to the compressible resilient nature of the foam core, with flexibility of manufacture to accommodate a wide variety of applications, while meeting stringent flammability standards. Once such flammability standard is the UL94 V0 vertical flame test, described in detail in Underwriter Laboratories Standard 94 entitled "Tests for Flammability of Plastic Materials for Parts in Devices and Appliances," 5th Edition, 1996, the disclosure of which is incorporated herein by reference in its entirety. In one embodiment, the shield may be manufactured by a continuous process, along a manufacturing line. A foam core is produced by mixing polyol and isocyanate, and passing the chemical mixture through a mix head. A metallized fabric or other conductive covering in the form of a roll having an adhesive film laminated along one side thereof is passed under an applicator which applies a layer of expandable carbon graphite on the adhesive film side of the metallized fabric. The metallized fabric with expandable carbon graphite is then passed under the mix head to receive a bead of the chemical mixture. The EMI gasket elements, namely the metallized fabric, the expandable carbon graphite, and the chemical bead are passed though a folding die to wrap the metallized fabric around the chemical bead. Then, the EMI gasket elements are optionally passed over a heated plate to thermally activate the adhesive and initiate foaming of the chemical bead. The EMI gasket elements are then passed through a heated continuous belt mold while the foam expands and conforms to the shape of the belt mold.

The heated belt mold can be made of two belts or, alternatively, of two belts and two belt inserts. In one embodiment, a split line of the two belt inserts is offset from a split line of the two belts. In yet another embodiment, one or both of the belt inserts have a projection extending from the belt insert that is narrower than the belt insert from which the projection extends to provide for lateral adjustment of the two belt inserts relate to each other. In another embodiment, the manufacturing line has an adjustable stage to align the wrapped metallized fabric with a nip formed by the continuous belt mold.

According to one alternative embodiment, the expandable carbon graphite may be disposed in a layer between the metallized fabric and the adhesive film. In yet another embodiment, the expandable carbon graphite may be disposed in the adhesive film located on the metallized fabric. Instead of foaming the core in place with a continuous molding process, the metallized fabric and expandable carbon graphite according to any of these embodiments can be wrapped around a pre-formed foam core and bonded thereto.

Brief Description of the Drawings

The above and further advantages of this invention may be better understood by referring to the following description, taken in conjunction with the accompanying drawings, in which:

FIG. 1A is a schematic diagram of one process and manufacturing line of the current invention for the manufacture of flame-retardant EMI gaskets;

FIG. 1B is a schematic diagram of an alternative process and manufacturing line of the current invention for the manufacture of flame-retardant EMI gaskets;

FIG. 1C is a schematic diagram of another process and manufacturing line of the current invention for the manufacture of flame-retardant EMI gaskets including an adjustable stage;

FIG. 2A is a cross-section of a rectangular flame retardant EMI gasket being formed by forming belts taken along section 2A-2A of FIG.1A;

FIG. 2B is a cross-section of a rectangular flame retardant EMI gasket being formed by forming belts and belt inserts with aligned split lines;

FIG. 2C is a cross-section of a rectangular flame retardant EMI gasket being formed by forming belts and belt insets with off-set split lines;

FIG. 2D is a cross-section of circular flame retardant EMI gasket forming belts and belt insets with off-set split lines, wherein one of the belt inserts has a projection;

FIG. 2E is a cross-section of a square flame retardant EMI gasket;

FIG. 2F is a cross-section of a D-shaped flame retardant EMI gasket;

FIG. 2G is a cross-section of a figure-8 shaped flame retardant EMI gasket;

FIG. 3 is a cross-section of a flame retardant EMI gasket in accordance with Example 1;

FIG. 4 is a cross-section of a flame retardant EMI gasket in accordance with Example 2;

FIG. 5A is a cross-section of belts and belt inserts for forming a custom EMI gasket; and

FIG. 5B is a cross-section of the custom EMI gasket formed in accordance with the apparatus of FIG. 5A.

Detailed Description of the Invention

Referring to FIG. 1A, shown is one process for manufacturing flame-retardant EMI gaskets. A roll of metallized fabric 100 provides a continuous source of metallized fabric 105 which has an adhesive backing 110 thereon. FIG. 1B illustrates an alternative process where the adhesive backing 110 may be supplied from a roll 104 and bonded to the metallized fabric 105 by heated rollers 106 and 107. Alternatively, the adhesive may be applied to the fabric 105 by a sprayer, roller, or other suitable method.

Applicator 115 holds a supply of expandable carbon graphite 120 or other flame retardant material. The expandable carbon graphite 120 can be Asbury Mills Expandable Carbon Graphite Flakes, which come from India and have audic content. The expandable carbon graphite 120 is inert in the EMI gasket and only reacts when heated by an external heat source of sufficient temperature, such as a flame. The expandable carbon graphite 120 provides the flame-retardant property to the EMI gasket by expanding when heated sufficiently, thereby preventing propagation of the flame front. The expandable carbon graphite 120 does not overly stiffen the EMI gasket if the expandable carbon graphite is a relatively small constituent of the volume of the EMI gasket, such as about 10% or less, preferably about 1.5% or less, more preferably about 0.7% or less. The applicator 115 applies the expandable carbon graphite 120 to the metallized fabric 105 in a generally uniform sprinkled distribution across at least a portion of the width of the fabric 105.

In the embodiment illustrated in FIG. 1A, the expandable carbon graphite 120 may be dispensed on the adhesive film 110 already formed on the metallized fabric 105. In the embodiment illustrated in FIG. 1B, the expandable carbon graphite 120 may be dispensed on the metallized fabric 105 between the adhesive film 110 and the metallized fabric 105. In yet another embodiment, the expandable carbon graphite 120 may be mixed into the adhesive, either in film or other form, and the adhesive with the expandable carbon graphite 120 therein applied to the metallized fabric 105.

A foam core 125 for the EMI gasket can be produced by a using a conventional chemical delivery system 130, such as that available from EMC^2 located in Sterling Heights, Michigan. The chemical delivery system 130 has two tanks 135, 140 and two pumps 145, 150. The foam 125 is produced by mixing polyol 155 and isocyanate 160. The polyol 155 can be FE3503GY from Plast-O-Meric Incorporated of Sussex, Wisconsin. The isocyanate 160 can be ISO 7000, also supplied by Plast-O-Meric Incorporated. The polyol 155 is stored in tank 135 and the isocyanate 160 is stored in tank 140. The polyol 155 and isocyanate 160 are pumped by respective pumps 145, 150 to a mix head 165 which has an internal beater which rotates to mix the polyol 155 and isocyanate 160 to create a chemical mixture 170 which foams after a time due to a chemical reaction process to produce the foam core 125. A bead of the unfoamed chemical mixture 170 is micropoured onto the metallized fabric 105 after application of the expandable carbon graphite 120.

The chemical mixture 170, the metallized fabric 105, and the expandable carbon graphite 120 are passed through a folding die 175 which wraps the metallized fabric 105 around the chemical mixture 170. The chemical mixture 170, the metallized fabric 105, and the expandable carbon graphite 120 may then be passed through or over an optional heating die 180 to activate the adhesive 110 on the metallized fabric 105 and accelerate the reaction process. In one embodiment, the heating die 180 is aluminum and can be heated to a relatively high temperature.

After passing through the optional heater 180, the chemical mixture 170, the metallized fabric 115, and the expandable carbon graphite 120 are passed through a heated dual belt mold 185. The heated belt mold 185 consists of two belts 190, 195, two drive pulleys 200, 205 and two follower pulleys 210, 215. The two belts 190, 195 form a continuous mold cavity for shaping the metalized fabric 105, expandable carbon graphite 120 and the chemical mixture 170 while it expands. In one embodiment, the belts 190 and 195 can be made of rubber and in another embodiment the belts 190 and 195 can be made of thermoplastic resin. The chemical mixture 170 should be delivered to the heated belt mold 185 within the cream time of the mixture to ensure the chemical mixture 170 enters the heated belt mold 185 prior to significant expansion. The heated belt mold 185 is heated by upper and/or lower heaters 220.

The reason for heating the heated belt mold 185 is to significantly decrease the amount of time required for expansion of the chemical mixture 170 into a stable foam. By reducing the expansion time, the length of the heated belt mold 185 can be significantly reduced. In an illustrative embodiment the heater 220 can heat the heated belt mold 185 to a temperature range

between about 160-185°F, which results in an expansion time of 45 seconds for a mixture of polyol 155 and isocyanate 160.

In alternative embodiments of the processes illustrated in FIGS. 1A and 1B, a premanufactured foam profile may be used in place of the expanding chemical mixture 170, in which case the continuous belt mold 185 can be substantially shortened or eliminated.

In another alternative embodiment, illustrated in FIG. 1C, an adjustable stage 280 may be used to accurately align the wrapped metallized fabric with a nip 212 formed by the continuous belt mold 185. The stage 280 may have multiple axes, for example X-Y-Z axes, controlled manually or using servo motors. FIG. 1C also shows that the belts 190, 195 may be housed in a heated chamber 290.

FIG. 2A illustrates a rectangular cross-section EMI gasket formed by belts 190 and 195. FIG. 2B illustrates how belt insets 235 and 240 may be placed in recesses formed in belts 190 and 195 to form a desired cross-section EMI gasket, which can be changed by changing solely the inserts 235, 240 instead of the belts 190, 195. FIG. 2C illustrates an alternative embodiment where the split line of the belt inserts 235, 240 are offset from the split line of the belts 190, 195 to facilitate proper mating and tracking. FIG. 2D illustrates another alternative embodiment, where at least one of the two belt inserts 235, 240 has a projection 237 which is narrower than the belt insert 235 from which it extends to provide lateral adjustment of the two belts 190, 195 to facilitate accurate mating of the contours formed in the inserts 235, 240. In the embodiment illustrated in FIG. 2D, the width (W1) of the projection 237, is less than the width (W2) of the belt insert 240. In addition, the belts 190, 195 can have reinforcing structures 238, such as steel cables, molded therein.

The sizes of the belts and belt inserts depend on the size and configuration of the EMI shield desired. For example, to produce a 0.25 inch round EMI gasket, the belts 190, 195 can be about 3 inches wide and 1 inch thick. The belt inserts 235, 240 can be about 1 inch wide and have an overall thickness from about 0.375 inches to 0.625 inches.

FIGS 2E-2G illustrate typical alternative cross-sections of flame-retardant EMI gaskets capable of being formed. FIG. 2E illustrates a square cross-section for a flame retardant EMI gasket 305. FIG 2F illustrates a D-shaped cross-section for a flame retardant EMI gasket 310. FIG. 2G illustrates a figure-8 cross-section for a flame retardant EMI gasket 315. Clearly, other cross-sections can be formed by this method.

As used herein, the term electrically conductive covering is meant to cover all manner of electrically conductive structure capable of at least partially surrounding a foam core, including metallized fabrics, foils, conductive polymers, flexible conductive ceramics, and the like. The term metallized fabrics includes articles having one or more metal coatings disposed on woven, nonwoven, or open mesh carrier backings and equivalents thereof. See, for example, U.S. Pat. No. 4,900,618 issued to O'Connor et al., U.S. Pat. No. 4,910,072 issued to Morgan et al., U.S. Pat. No. 5,075,037 issued to Morgan et al., U.S. Pat. No. 5,082,734 issued to Vaughn, and U.S. Pat. No. 5,393,928 issued to Cribb et al., the disclosures of which are herein incorporated by reference in their entirety.

Metallized fabrics are commercially available in a variety of metal and fabric carrier backing combinations. For example, copper on a nylon carrier, nickel-copper alloy on a nylon carrier, and nickel on a polyester mesh carrier are available under the registered trademark Flectron® from Advanced Performance Materials located in St. Louis, Missouri. An aluminum foil on a polyester mesh carrier is available from Neptco, located in Pawtucket, Rhode Island. Other suitable metals include silver, tin, zinc, palladium, gold, and platinum. Electrically conductive paints could also be used, as well as metallic vapor depositions on suitable substrates. The choice of metal is guided, in part, by installation conditions of the EMI shield. For example, a particular metal might be chosen due to the composition of abutting body metal in the enclosure to avoid galvanic corrosion of the EMI shield which could increase electrical resistance and deteriorate electrical grounding performance.

Metallized tapes are desirable both for ease of application to the foam core as well as durability. One method of manufacture employs the metallized fabric in tape form of suitable width backed with a thermally activated glue. The glue may cover substantially the entire backing or solely portions thereof, such as along the edges.

Manufacturing flame-retardant EMI gaskets in accordance with FIGS. 1A, 1B and 1C on a process line utilizes less metallized fabric than fully laminated designs, resulting in cost savings. Tight manufacturing tolerances and superior product appearance may also be maintained. Due to the presence of the expandable carbon graphite, the EMI shield not only provides EMI shielding but also meets the UL94 V0 flammability standard.

By providing the expandable carbon graphite around the foam core, instead of mixing the expandable carbon graphite with the chemicals, the chemical delivery system is unaffected.

Mixing the expandable carbon graphite with the chemicals prior to foaming has been shown to result in a significant increase in viscosity, which affects mixing in and dispensing from the mix head 165. The apparatus and methods according to the invention, however, may also be used to manufacture EMI gaskets without the expandable carbon graphite or other flame retardant materials.

EXAMPLES

Typical embodiments of the present invention are illustrated in the following examples.

Example 1 describes the production of a 0.25 inch square gasket having an adhesive tape mounting strip temporarily covered by a release liner. See FIG. 3. A process line may start with a roll of metallized fabric on a spool containing a fabric ribbon such as 1.0 inch wide Flectron Nickel/Copper nylon ripstop. The process line also has an adjustable position stage and a fabric tension mechanism such as driven rollers. The metallized fabric is pulled with a variable speed puller with a length extension compensation device. The process line also has fabric guide rollers, a folding die, and a heating die mounted on the stage which is adjusted to allow accurate positioning of the filled, folded metallized fabric with a nip of the continuous belt.

Foam is produced using a two tank material storage system which includes an agitating system and dry air source. The two tank material storage system also has two zenith pumps with an adjustable flow rate and a changeable gear. The two materials stored in the two tanks for making the foam core 400 are Plasto-O-Meric Poloys FF3527 and Plasto-O-Meric Isocyanate 7000. The two tank material storage system also has a variable dispensing gun with adjustable speed motor as well as a flow rate meter. A continuous belt mold is used with two belts with cavities for accepting two belt mold inserts with a locking device. The continuous belt mold is located in a heated chamber with a temperature control and monitoring windows. An adhesive tape 410, such as PSA 3M 9485PC, which is 0.1 inches wide is attached to the metallized fabric 420 after exiting the mold. Finally, the adhesive tape 410 is covered by a release liner 425, which can be an extruded liner from 3M, 9485PC, and can be 0.25 inches wide to facilitate removal at time of installation of the EMI gasket. The gasket can be produced with or without expandable carbon graphite or other flame retardant disposed between the metallized fabric 420 and the foam core 400.

Example 2 describes the production of a C-fold gasket roughly 0.4 inches high. The C-fold gasket includes a stiffener and adhesive tape covered by a release liner, as depicted in FIG. 4.

The process line used in Example 2 is very similar to the process line used in Example 1, however Example 2 uses different materials. The metallized fabric 500 is 1.675 inches wide Flectron Nickel/Copper nylon ripstop. The stiffener 505 is General Electric aircraft grade polycarbonate, about 0.375 inches wide and 0.015 inches thick. The adhesive tape 510 is PSA 3M 9485PC and is about 0.187 inches wide. The release liner 515 is an extruded liner, 3M 950EK, and is about 0.500 inches wide. The foam core 520 is produced using Plast-O-Meric Polyols FF3527 and Plast-O-Meric Isocyanate 7000. The metallized fabric 500 may partially or wholly cover the stiffener 505. The gasket may or may not include an expandable graphite layer.

Example 3 describes production of a custom EMI gasket that can manufactured using the present invention. FIG. 5A illustrates cross-sections of belts 600, 605 with belt inserts 610, 615 having offset split lines for manufacturing the custom EMI gasket 620 depicted in cross-section in FIG. 5B.

Variations, modifications, and other implementations of what is described herein will occur to those of ordinary skill in the art without departing from the spirit and the scope of the invention.

What is claimed is:

Claims

1. A method of manufacturing a shield for shielding electromagnetic interference, the method comprising the steps of:
providing a metallized fabric;
applying a foamable mixture for forming a foam core on the metallized fabric;
wrapping the metallized fabric at least partially around the foamable mixture; and
passing the wrapped metallized fabric containing the foamable mixture through a heated continuous belt mold.

2. The method of claim 1 further comprising providing a flame retardant material with the metallized fabric.

3. The method of claim 2 wherein the flame retardant material is dispensed on the metallized fabric.

4. The method of claim 2 wherein the metallized fabric further comprises an adhesive and the flame retardant material is in the adhesive.

5. The method of claim 2 wherein the metallized fabric further comprises an adhesive and the flame retardant material is between a substrate of the metallized fabric and the adhesive.

6. The method according to claim 2 wherein the flame retardant material comprises expandable carbon graphite.

7. The method according to claim 1 wherein the foamable mixture comprises polyol and a catalyst.

8. The method according to claim 1 wherein the foam core comprises urethane.

9. The method according to claim 2 further comprising the step of heating the wrapped metallized fabric containing the foamable mixture and the flame retardant material prior to passing the wrapped metallized fabric containing the foamable mixture and the flame retardant material through the heated continuous belt mold.

10. The method according to claim 1 wherein the heated continuous belt mold comprises a dual belt mold.

11. The method according to claim 10 wherein the dual belt mold comprises two belts and two belt inserts.

12. The method according to claim 11 wherein a split line of the two belt inserts is offset from a split line of the two belts.

13. The method according to claim 10 wherein at least one of the two belt inserts further comprises a projection, wherein the projection is narrower than the belt insert from which the projection extends to provide for lateral adjustment of the two belts.

14. The method according to claim 1 further comprising providing an adjustable stage to align the wrapped metallized fabric with a nip formed by the continuous belt mold.

15. A flame retardant metallized fabric comprising a metallized fabric substrate, a flame retardant material, and an adhesive layer.

16. The flame retardant metallized fabric of claim 15 wherein the flame retardant material is between the metallized fabric substrate and the adhesive layer.

17. The flame retardant metallized fabric of claim 15 wherein the flame retardant material is in the adhesive layer.

18. An apparatus for manufacturing a shield for shielding electromagnetic interference, the apparatus comprising a manufacturing line comprising, in serial downstream relation:
a metallized fabric source;

a foam source;

a folding die; and

a heated continuous belt mold.

19. The apparatus of claim 18 further comprising a heating die disposed upstream of the continuous belt mold.

20. The apparatus of claim 18 further comprising an adjustable stage disposed upstream of the continuous belt mold.

21. The apparatus of claim 18 further comprising a flame retardant material source disposed upstream of the continuous belt mold.

22. The apparatus of claim 21 wherein the flame retardant material source is disposed upstream of the foam source.

23. The apparatus of claim 18 wherein the foam source comprises:

tanks for holding polyol and a catalyst;

a pump; and

a mixing head.

24. The apparatus of claim 18 wherein the foam source comprises a foam profile.

25. The apparatus of claim 18 further comprising an adhesive source dispensing an adhesive for mating with fabric dispensed from the metallized fabric source.

26. The apparatus of claim 25 wherein the adhesive comprises a strip of adhesive.

27. The apparatus of claim 18 wherein metallized fabric from the metallized fabric source includes an adhesive backing.

28. The apparatus of claim 18 wherein the continuous belt mold comprises a dual belt mold forming a nip.

29. The apparatus of claim 28 wherein the dual belt mold comprises two belts and two inserts.

30. The apparatus of claim 29 wherein a split line of the two belt inserts is offset from a split line of the two belts.

31. The apparatus of claim 28 wherein at least one of the two belt inserts further comprises a projection, wherein the projection is narrower than the belt insert from which the projection extends to provide for lateral adjustment of the two belts.

32. The apparatus of claim 21 wherein the flame retardant material source dispenses expandable carbon graphite.

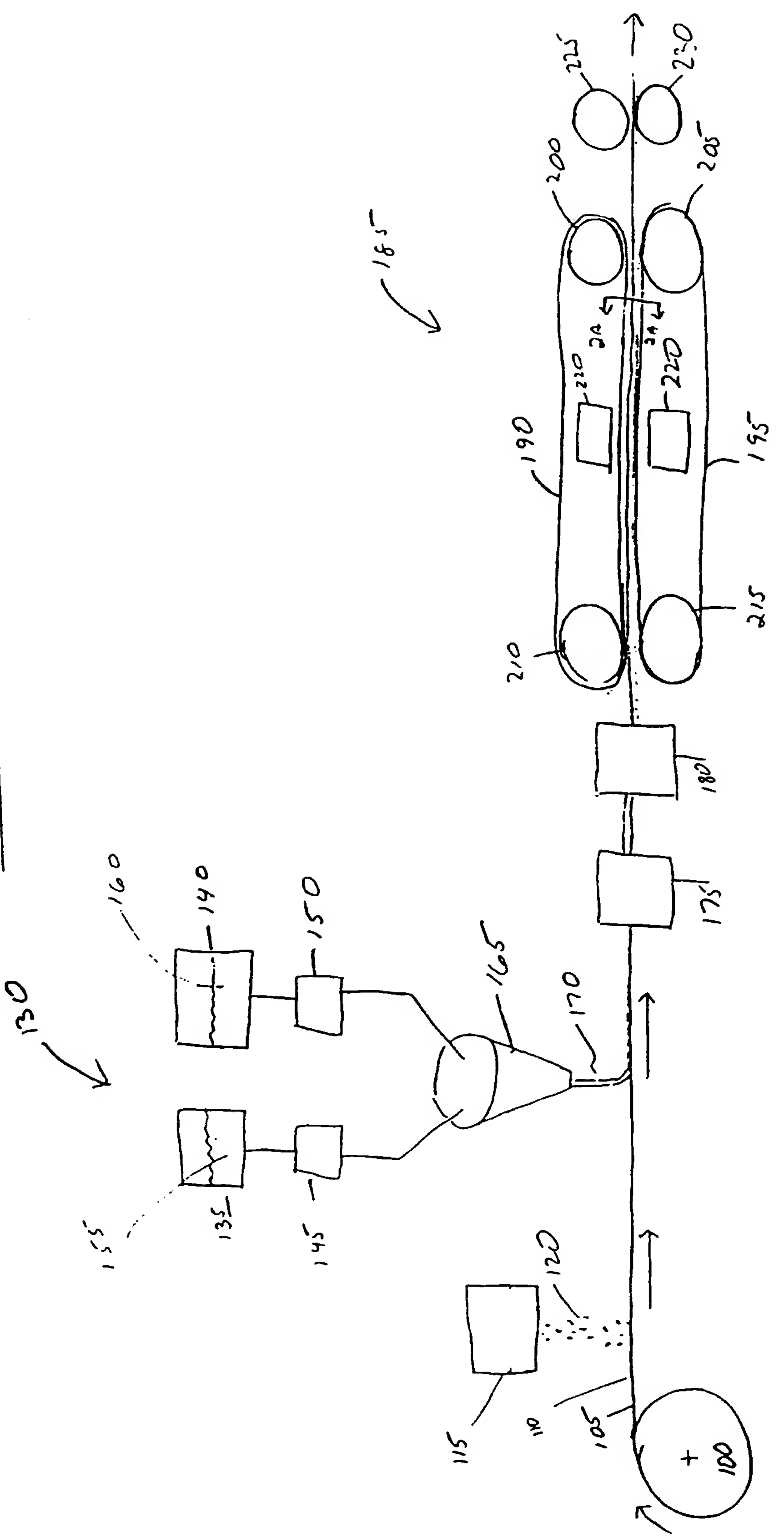

100
105
110
115
120
130
135
140
145
150
155
160
165
170
175
180
185
190
195
200
205
210
215
220
225
230

Fig. 1A

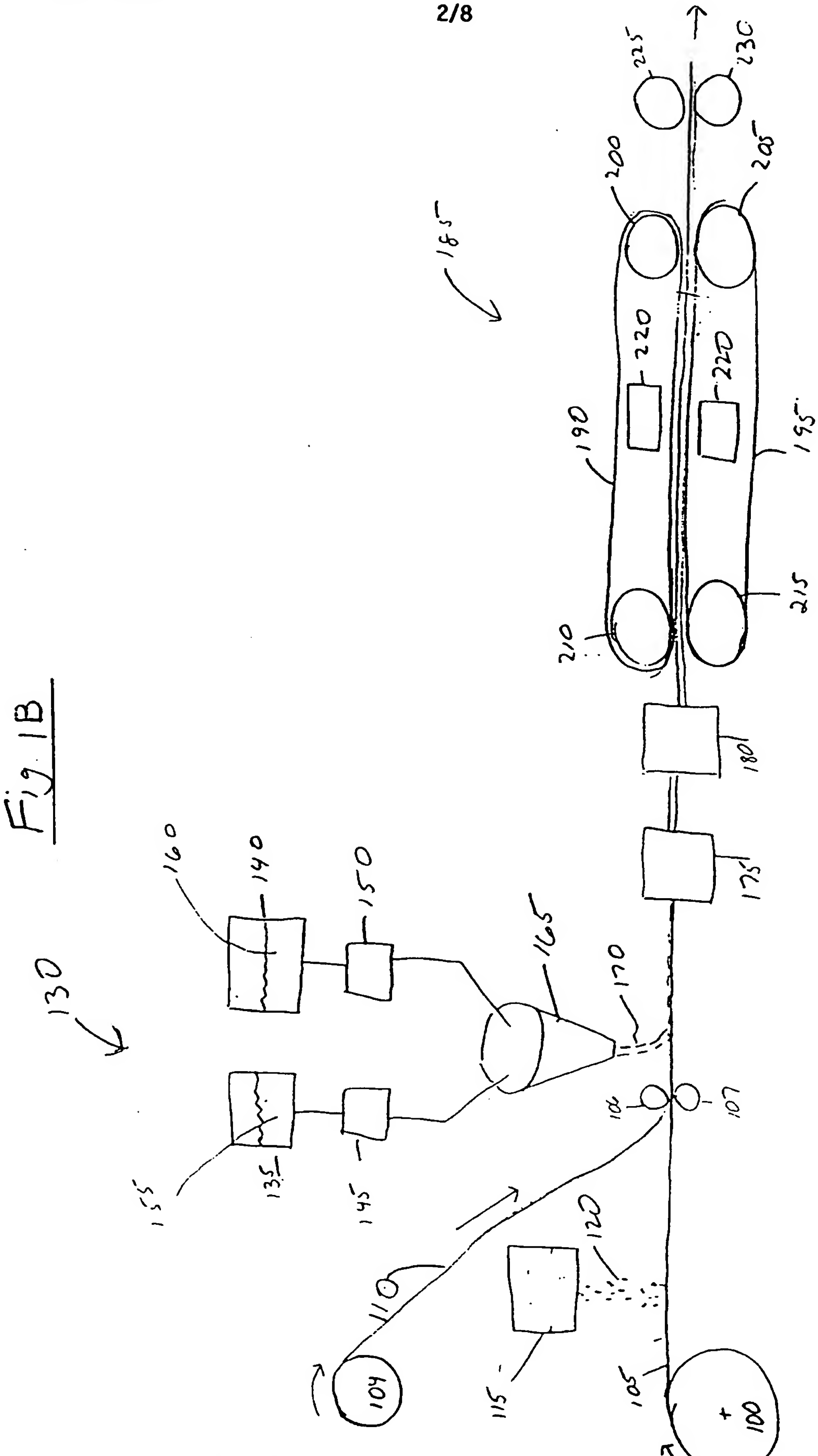

130
135
140
145
150
155
160
165
170
175
180
185
190
195
200
205
210
215
220
220
225
230
100
104
105
106
107
110
115
120

Fig 1B

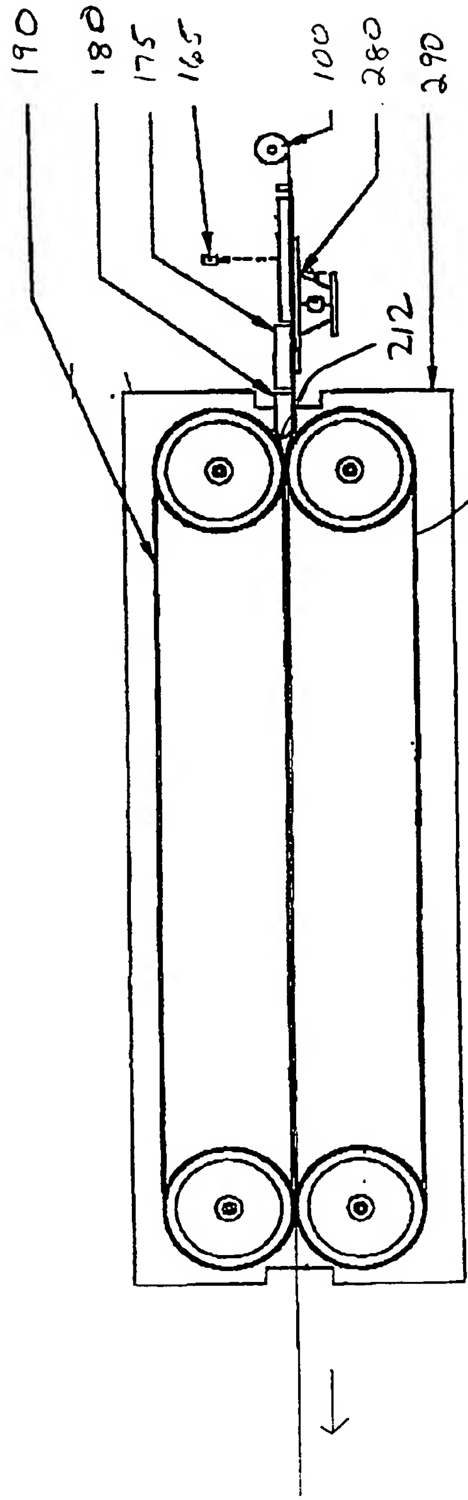


FIG. 1C

BEST AVAILABLE COPY

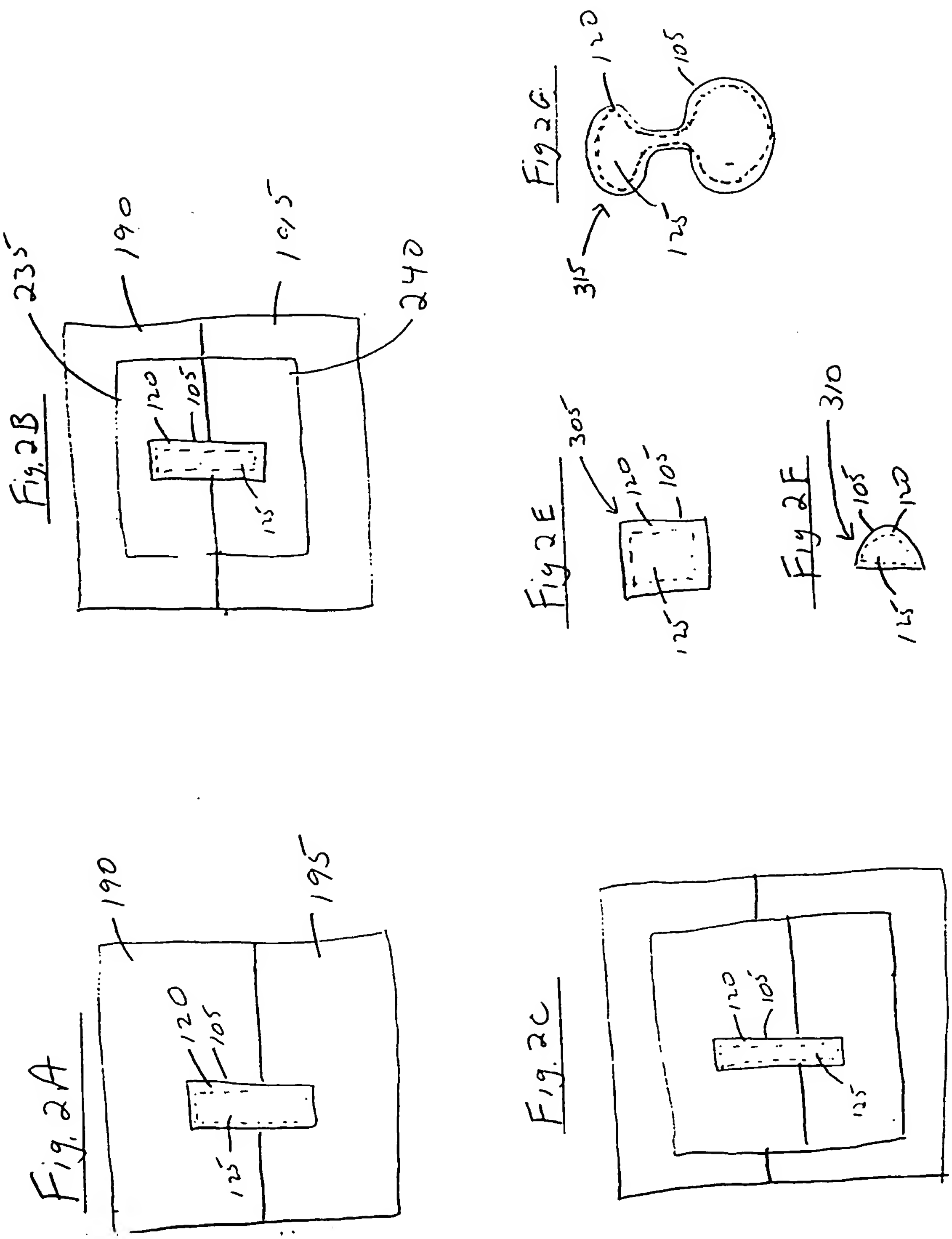


Fig. 2A

Fig. 2B

Fig. 2C

Fig. 2E

Fig. 2F

Fig. 2G

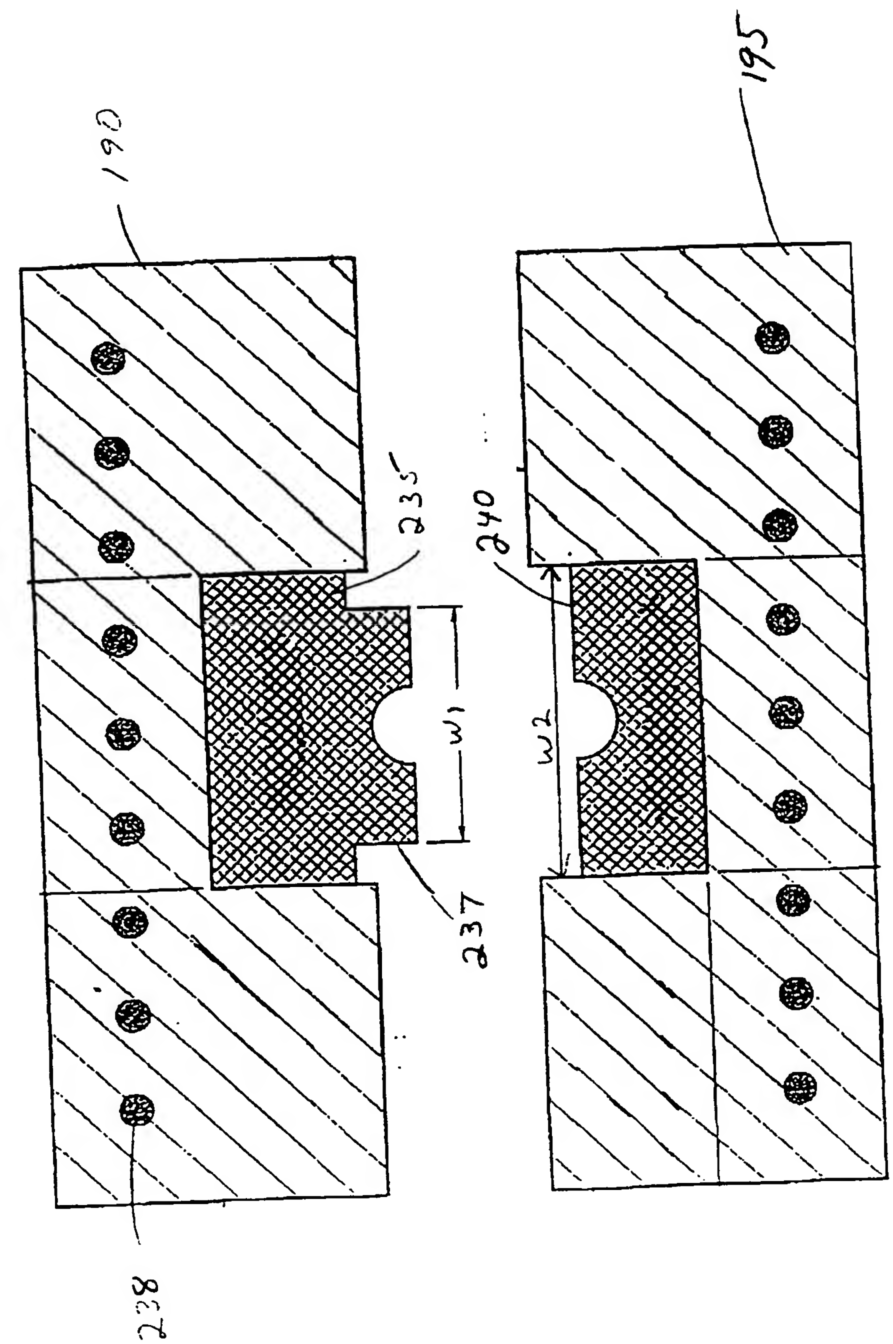


FIG. 2D

BEST AVAILABLE COPY

FIG. 3

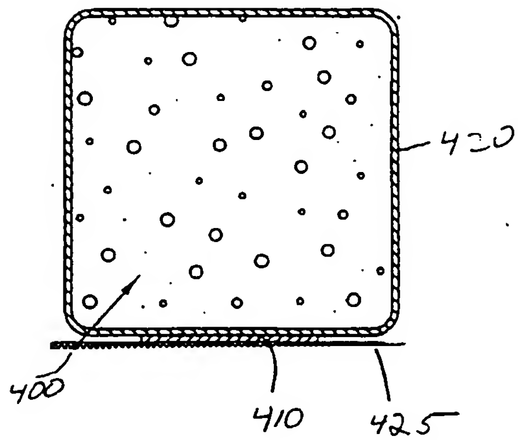


FIG. 4

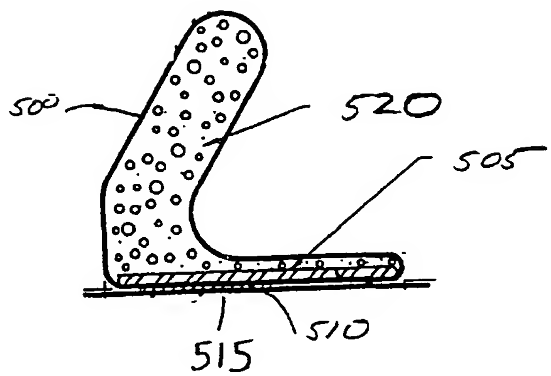


FIG. 5B

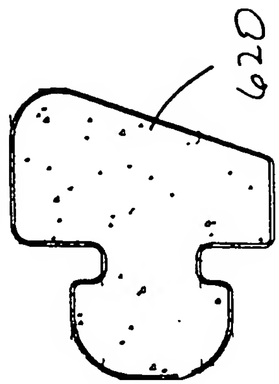


FIG. 5A